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Dimensional Stability and Biological Resistance of Particleboard from Acetylated Albizzia Wood Particles

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Abstract—Dimensional stability and biological resistance of low-density acetylated particleboards from tropical fast-growing and perishable timber, *Albizia facata*, were investigated. Acetylated particles with 18% weights gain (WG) were pressed into particleboards using phenol formaldehyde (PF) resin and isocyanate (IC) resin for adhesives. Control boards made with PF adhesive swelled faster and to a greater extent than did control boards containing IC adhesive. Boards made from acetylated particles showed greater reduced rate and extent of swelling after water soaking test or dry/wet treatment for both types of adhesives as compared to control boards. Acetylated particleboards subjected to burial in moist unsterile soil were virtually unchanged in color and texture with little weight loss showing the potential performance in severe biological conditions.

Key words: *Albizia falcata*, acetylation, particleboard, dimensional stability, decay resistance

1. Introduction

Albizia (*Albizia falcata* Backer) is a fast-growing and lesser-used species planted in the tropics. It is a lightweight wood with specific gravities (SG) ranging from 0.2 to 0.5, and categorized as a poor structural timber in terms of its strength and durability.

To expand its utilizations, we have investigated the possible production of particleboards. Low-density particleboard was produced from this species and some superior structural properties have been reported¹⁾. However, it was also shown that albizzia particleboards have poor dimensional stability and low resistance to decay and termite attack. Physical and biological properties, such as those related to

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dimensional stability, and resistance against biodeterioration, are greatly improved by acetylation of the particles^{2~5}). Penetration of reacting chemicals is quick and complete with small particles of low-density wood and chemical recovery after reaction is easily done.

In this report, properties enhancement of albizzia particleboards due to acetylation is discussed with emphasis on dimensional stability under repeated conditions of dry and wet, and biological resistance against long time exposure to moist unsterile soil.

2. Experimental

2.1 Preparation of acetylated particleboard

The raw material used was logs of albizzia (*A. falcata*) having an air-dry density of 0.3 g/cm³, which had been cut from trees planted in Indonesia and logged after ten years. Wafers were prepared with a disc-flaker, and then hammer-milled into flake-type particles. The average dimensions of the particles were 30 mm in length, 2.0 mm in width, and 0.49 mm in thickness.

Particles with four percent moisture content were placed in a stainless-steel mesh container. The container was dipped in a tank containing acetic anhydride, preheated and conditioned at 120°C for 24 hours. The reacted particles were rinsed in running water to remove the unreacted acetic anhydride and the by-product acetic acid until the smell of these chemicals disappeared. The particles then were dried in hot air. Acetylated particles with a weight gain (WG) at about 18 percent were produced by this treatment.

The particleboards made from untreated and acetylated particles were produced using phenol formaldehyde (PF) or isocyanate (IC) adhesives as binder resins. The resin content level was eight percent resin solids, based on oven-dry weight of particles. To obtain a suitable viscosities of adhesives for spraying, acetone was added to the IC resin at 20 percent based on the weight of resin solids, and PF resin were diluted to 50 percent resin concentrations with water. Untreated and acetylated particles with a five percent moisture content were used for PF resin, and those with a ten percent moisture content were used for IC resin to provide moisture for the curing reaction. Hand-formed particle-mats were pressed at 160°C to the fixed thickness of 12 mm. The pressure of 20 kg/cm² was initially applied for 30 seconds, and then reduced while the rest of 4 minutes for IC, 12 minutes for PF boards. The intended specific gravity of each board was 0.5 in air-dry condition for control and acetylated particleboards.

2.2 Preparation of particleboards for testing

Each particleboard was cut into pieces (50×50×12 mm), and weight and thick-

nesses were measured for testing of physical and biological properties. Thickness measurements were taken at five points on each face (each corner and center) and subsequent measurement were taken at the same points.

2.3 Water soaking tests

Repeated water soaking tests were run as previously described⁶⁾. Each cycle consisted of water soaking for 5 days followed by oven-drying (O.D.) for 2 days. Six cycles were run. Thickness swelling was calculated as a percentage of the original thickness (O.D. board).

2.4 Humidity tests

Oven-dried specimens were placed in constant humidity rooms at 30, 65 and 90% relative humidity (RH) and 27°C. After 21 days the specimens were weighed and the equilibrium moisture content (EMC) were determined.

Separate specimens were placed in a humidity room at 30% RH and 27°C. The thickness was determined after 21 days. The specimens were then placed in a humidity room at 90% RH and 27°C for another 21 days, whereafter the thickness was measured. This procedure was repeated for a total of four cycles of 30 to 90% RH. The specimens were then oven-dried and the thickness determined. Changes in thickness were determined as a percentage of the original thickness (O.D. board).

2.5 Exposure in unsterile soil

The biological tests under exposure in unsterile soil were conducted at two different places. Fungal cellar tests were run as previously described⁷⁾ by one of the authors at The Swedish University of Agriculture Sciences. Particleboard specimens, made from untreated particles and from particles acetylated at about 18% WG, were incubated at approximately 25°C in moist unsterile soil. At 1-month intervals, each specimen was removed from test and inspected. It was determined that brown-, white-, and soft-rot fungi and tunneling bacteria were among the micro-organisms present in the soil. Inspections were carried out for 6 months. Degree of board swelling was also noted.

Another soil-burial tests were run by the first author at Kyoto University as described previously⁸⁾. The specimens of the control and acetylated particleboards bonded with IC and PF resins were incubated at about 26°C in moist unsterile soil enriched with humus. Exposure in the soil was made for 9 months, which was a test period long enough for the control boards to be severely degraded. After the test was completed, small specimens were prepared for SEM (scanning electron microscopy) observations. Small specimens removed from the test were mounted on specimen stubs, and then coated with gold for examination in the

Hitachi S-500 SEM.

3. Results and Discussion

3.1 Dimensional stability

The previous report showed that the flexure properties of acetylated albizzia particleboards decreased with increase of acetyl weight gain, and the values of modulus of rupture (MOR) were 20~25% less in the boards produced from acetylated particles of 18% weight gain than those of control boards for both adhesives of PF and IC¹⁰⁾. Under wet conditions, however, high MOR values were obtained in the boards made from highly acetylated particles as compared to wet control boards.

Table 1 shows the EMC of the control and acetylated particleboards at each relative humidity condition. The lowest EMC was obtained for the acetylated boards bonded with IC resin, where the EMC was reduced over 50% at 65% RH and over 65% at 90% RH. The reduction was lower for the PF boards as shown by Tillman *et al.*⁹⁾

Table 1. Equilibrium moisture content (EMC) of particleboards made from acetylated albizzia particles.

Treatment	Adhesive	EMC (%) at		
		30% RH	65% RH	90% RH
Control	IC	5.1	9.4	16.7
Acetylated	IC	2.2	4.5	7.6
Control	PF	5.4	9.5	19.7
Acetylated	PF	2.9	6.4	14.7

Figure 1 shows the rate of swelling in liquid water for the PF and IC boards. The rate of swelling was higher for the PF control board as compared to that of the IC control board, but the extent of swelling was about the same for both boards in which the particles were acetylated. Wood acetylation reduced the extent of board swelling to less than 7% while the control boards made from untreated particles swelled approximately 28% for PF and 20% for IC boards, respectively. The tendency for the reduction in thickness swelling is very similar to the result reported by Rowell and others³⁾. The overall swelling of control and acetylated boards bonded with IC and PF resins was smaller in this study as compared to the result of them. Using low-density raw materials to produce particleboards accounts for the lower thickness swelling.

Thickness changes in the repeated water-soaking tests are shown in Fig. 2.

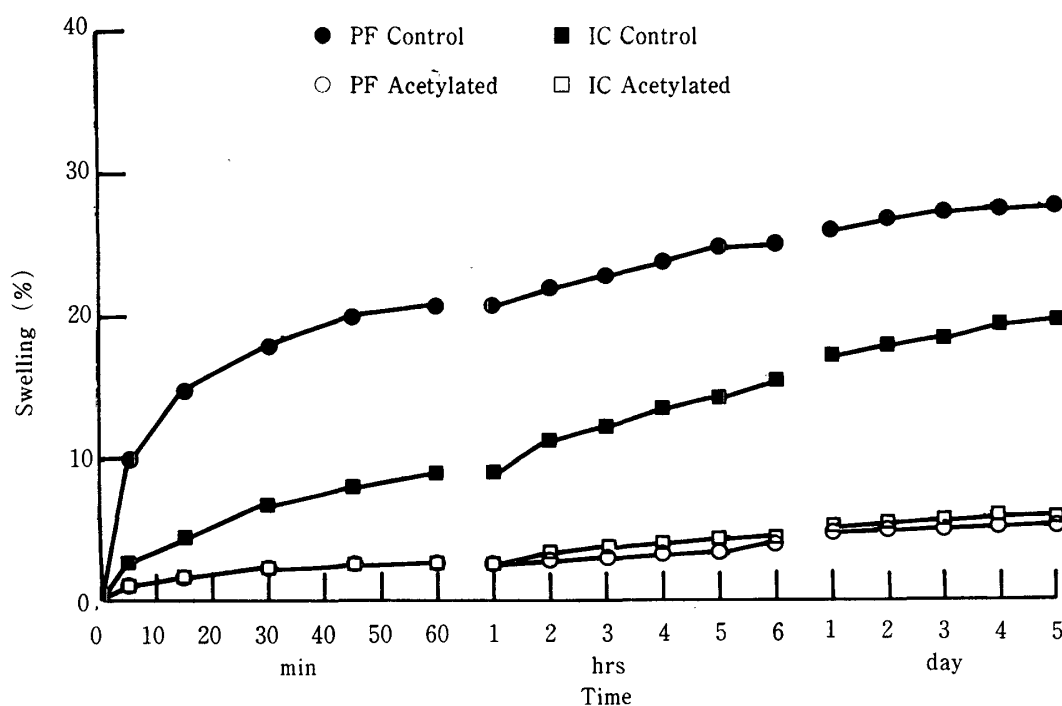


Fig. 1. Rate of swelling in liquid water of albizzia particleboards made from control and acetylated particles.

Both boards with untreated particles swelled much more than boards with acetylated particles. For the board made from acetylated particles of a weight gain of 18%, the maximum swelling was reduced to about 10%.

Figure 3 shows the thickness changes of PF and IC boards at 30 and 90% RH. Boards made from acetylated particles swelled at about 7% on the final 30% to 90% cycle, while boards made with untreated particles swelled more than 20% on the same cycle. This may be due to the fact that the less-hygroscopic groups in wood cause less moisture to be absorbed, and that most of the irreversible stresses do not occur in boards made from acetylated particles.

3.2 Decay resistance

Weight losses in the decay tests by the conventional method have already been reported¹¹⁾. Decay of albizzia particleboards by each pure culture of a brown- or a white-rot fungus was nearly zero for both IC and PF boards at 12% WG of acetylation, and was almost completely suppressed at 18% WG. In comparing the decrease in relative decay rate, *Tyromyces palustris* was less affected by acetylation than *Coriolus versicolor* causing weight losses in IC boards even at 12% WG, at which decay was almost zero for the latter fungus. Acetylated albizzia particles alone showed no weight loss using the brown-rot fungus *T. palustris* at 20% WG, and at 15% when the white-rot fungus *C. versicolor* was used. In most cases, particleboard

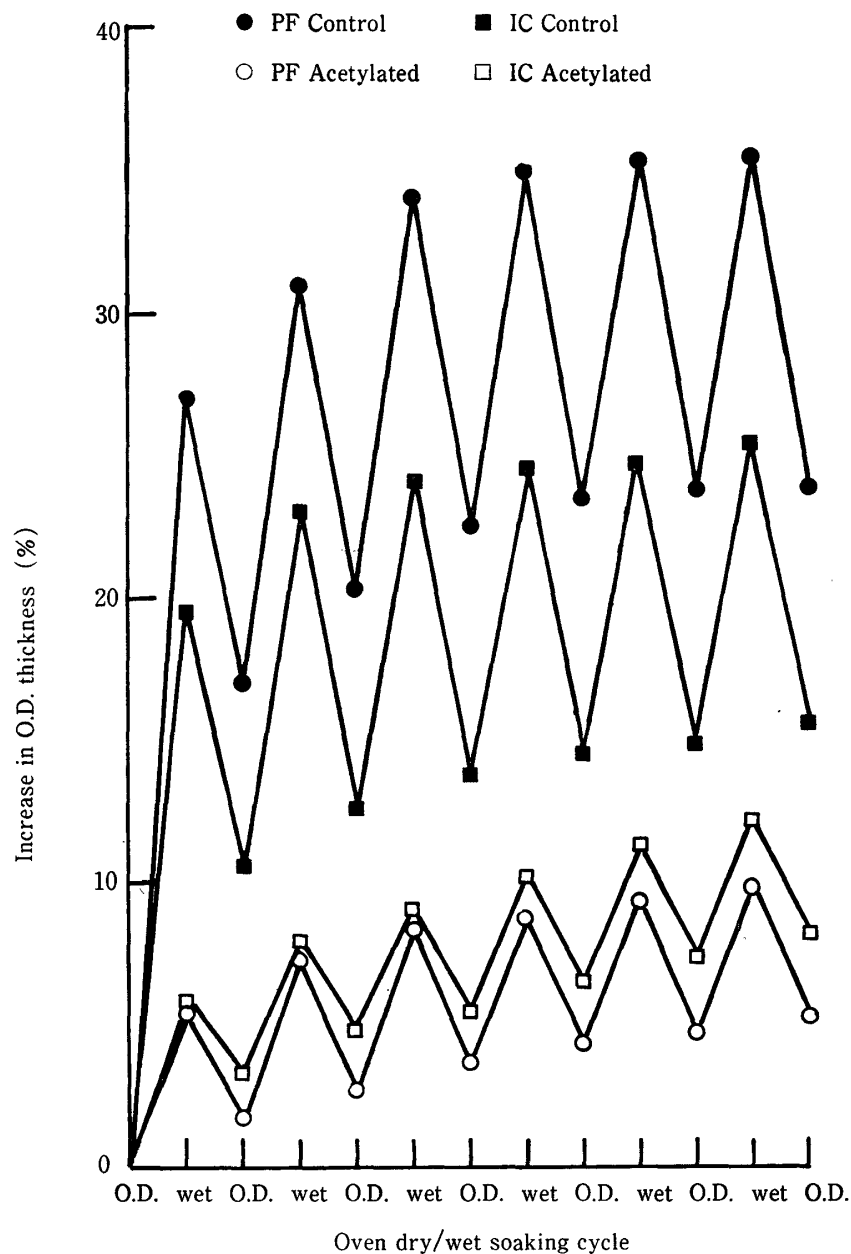


Fig. 2. Changes in thickness in repeated water swelling test of albizzia particleboards made from control and acetylated particles.

has a higher decay resistance than its original particle, because of several factors in board production.

Specimens observed after burial in moist unsterile soil showed that control boards were darkened intensely after burial, whereas specimens acetylated at 18% WG were virtually unchanged in color and texture (Fig. 4). Table 2 shows the results of a 6-month test of fungal cellar and a 9-month test in the soil. Control boards made with both adhesives are attacked to the same extent, losing about 45

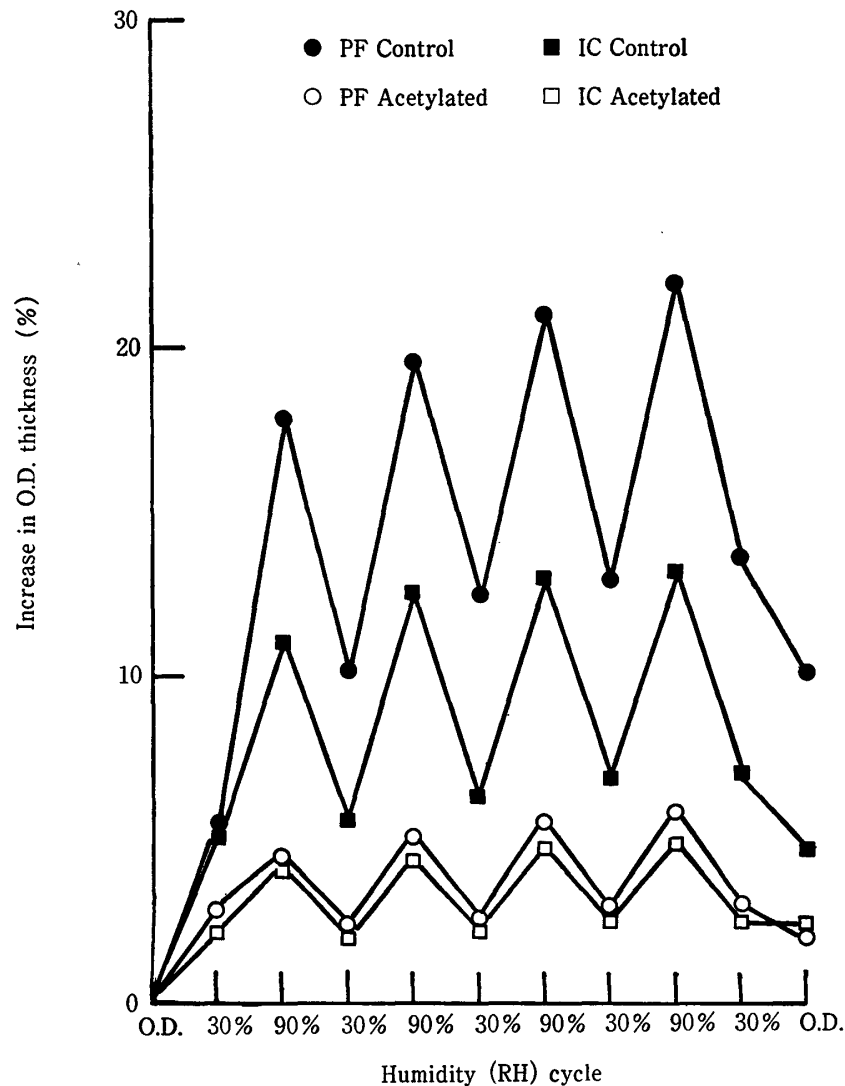


Fig. 3. Changes in thickness at 30% and 90% RH of albizzia particleboards made from control and acetylated particles.

percent weight after 9 months burial in soil. Particleboards made from the acetylated particles were very resistant to attack by the mixed organisms in soil.

In particleboards exposed to decay fungi, mycelial invasion was initiated within a short time and rapid colonization of fungi occurred in the microspaces of boards. Mycelium and strands were observed to develop on the surfaces of particles causing reduction of the glue bonding with little weight loss of the wood⁸⁾.

The fractured surfaces of control board exposed to soil burial for 9 months showed the active colonization of decay fungi and bacteria with apparent decomposition of the wood particles (Fig. 5-A, B, C). The colonization of decay fungi was also detected by SEM in the void spaces of acetylated particleboards. The pro-

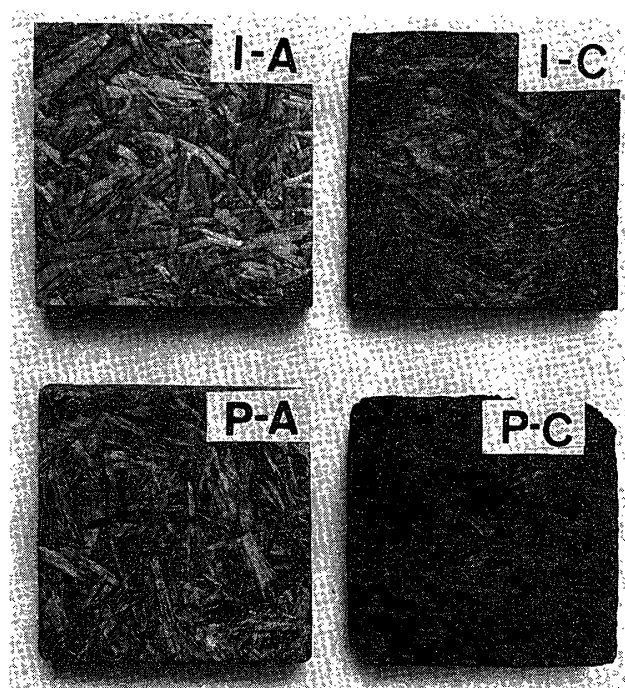


Fig. 4. Control and acetylated albizzia particleboards after 9 months exposure to moist unsterile soil. Note; I-A: IC acetylated, I-C; IC control, P-A; PF acetylated, P-C; PF control board.

Table 2. Biological decomposition of albizzia particleboards made from control and acetylated particles after 6 months and 9 months exposure in unsterile soil.

Treatment	Adhesive	6 months test* ¹ Rating* ³	9 months test* ² Weight loss* ⁴ (%)
Control	IC	3	43.6
Acetylated	IC	0	2.8
Control	PF	3	46.8
Acetylated	PF	0	2.2

*¹ Fungal cellar test for 6 months. *² 9 months burial in moist unsterile soil. *³ Rating system: 0-no attack, 1-slight attack, 2-moderate attack, 3-severe attack, 4-destroyed. *⁴ Average of 9 specimens.

portion of glue-line failure increased after exposure to decay attack in control boards, while acetylation reduced the attacks in the glue lines as well as reducing erosion of the wood particles (Fig. 5-D).

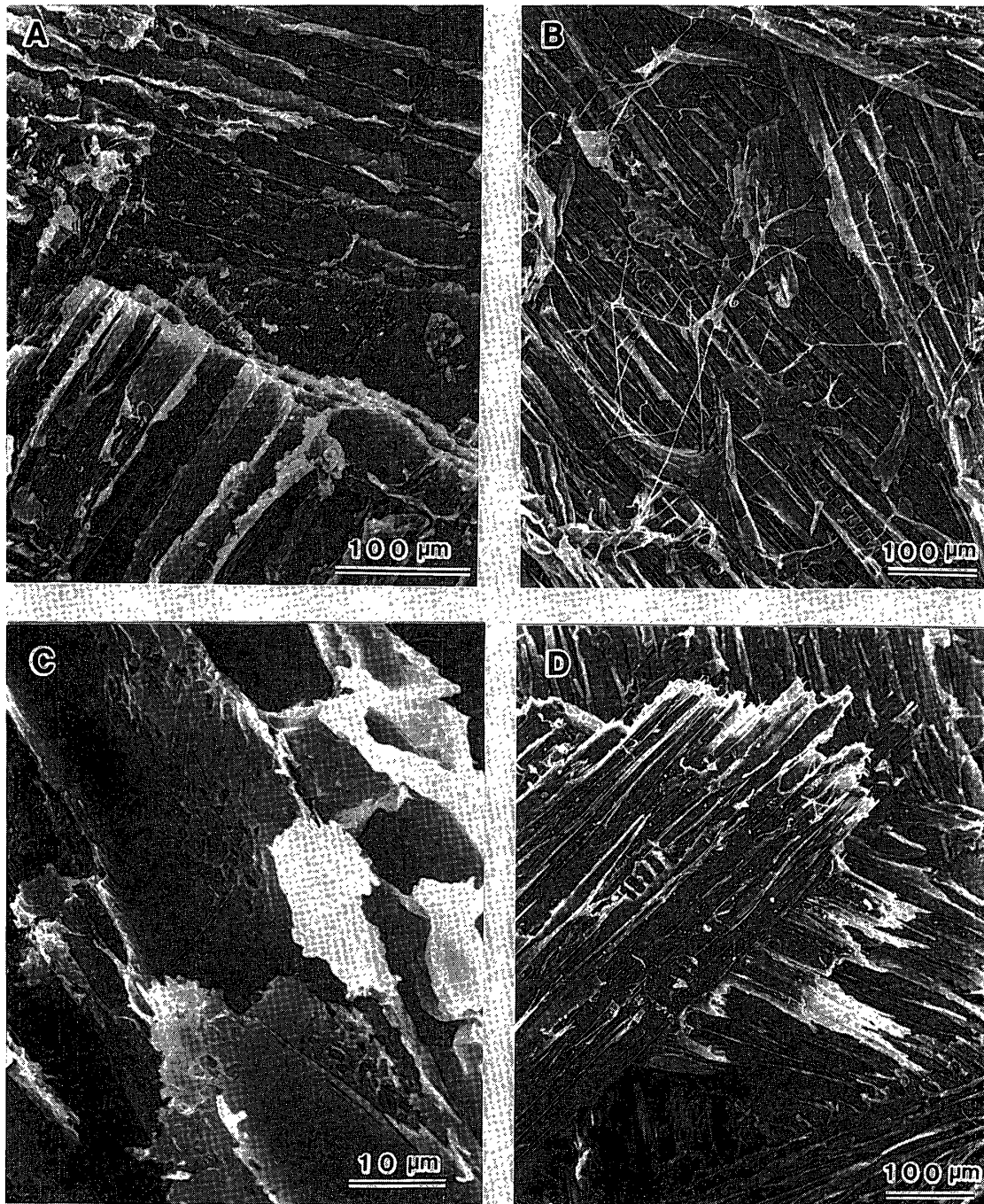


Fig. 5. Scanning electron micrographs of the fractured surfaces of Albizzia particleboards after soil-burial for 9 months.

Note; A, B, C: Control IC board, D: Acetylated IC board

A: The particles are so friable as to permit clear breaks in the transverse direction.

B: Fungal mycelium colonize in the void spaces of particleboard and develop in the glue lines.

C: Bacterial attack is observed in the inner surfaces of tracheids

D: Fractured surfaces demonstrate bristling of undecayed wood particles torn off.

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